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FLUCTUATION OF BACTERIAL DENSITY IN THE RED RIVER AT EMERSON

DURING A 36-HOUR PERIOD; AUGUST 9 - 10, 1988

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Conservation and Protection
Environment Canada, 1990

91-05937/

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ABSTRACT

Fluctuation of bacterial density in the Red River at Emerson during a 36-hour period (August 9 - 10, 1988) was studied. The study has revealed that the fluctuation was substantial; but after taking into account the analytical variation, it was less than an order of magnitude. Higher total coliform densities were detected during the day time while higher streptococci densities occurred during the night. The bacterial density was generally independent of DO, temperature, pH, conductivity and turbidity. The FC/FS ratio suggested non-human sources for much of the bacteria present in the Red River at Emerson. An evaluation of the historical data also revealed that in recent years, primarily resulting from the cessation of the accidental waste discharges, the total and fecal coliform densities had significantly decreased.

The study also revealed that with the possible exception of turbidity, the Red River was virtually homogeneous for temperature, DO, pH and conductivity, and for the latter three, the daily fluctuations were also relatively small.

RÉSUMÉ

L'on a procédé, à Emerson, à une étude des variations de la concentration bactérienne dans la rivière Rouge, au cours d'une période de 36 heures (les 9 et 10 août 1988). L'étude a révélé que les variations étaient importantes; cependant, après avoir tenu compte des variations dues à l' analyse, on s'est rendu compte qu'elles étaient inférieures à une décimale. L'étude révèle une concentration totale de coliformes plus élevée pendant la journée tandis qu'on remarque une concentration plus élevée de streptocoques pendant la nuit. La concentration bactérienne ne présentait en général aucun rapport avec les concentrations d'oxygène dissous ni la température, ni le pH, ni la conductivité, ni la turbidité. Dans le cas de la majorité des bactéries présentes dans la rivière Rouge à Emerson, la proportion de coliformes et de streptocoques fécaux laissait à penser que les bactéries n'étaient pas d'origine humaine. Un examen des données historiques a permis également de constater qu'au cours des dernières années, les concentrations totales et les concentrations de coliformes fécaux étaient très nettement moins importantes, ce qui s'explique surtout pour la suppression des rejets accidentels de déchets.

L'étude a également révélé que, à l'exception peut-être de la turbidité, les eaux de la Rivière rouge étaient virtuellement homogènes pour ce qui est de la température, de l'oxygène dissout, de l'acidité et de la conductivité et que, dans le cas de ces trois derniers éléments, les variations quotidiennes étaient également relativement minimes.

FLUCTUATION OF BACTERIAL DENSITY IN THE RED RIVER AT EMERSON DURING A 36-HOUR PERIOD

1.0 INTRODUCTION

As part of Environment Canada's ongoing routine water quality monitoring program on the Red River at Emerson (Figure 1), total and fecal coliform (TC and FC) measurements started in 1976. These monthly measurements were carried out at various times of the day, generally before noon during the first week of each month. Historical data in Figure 2 show that the bacterial density fluctuated substantially, and in recent years the TC and FC densities have decreased and reached a relatively stable condition. This decrease probably reflects improved waste treatment practices and regulated discharges of municipal and industrial sources as well as better agricultural practices. In order to evaluate the routinely collected data, and to review the apparent decrease, a study consisting of hourly sampling was undertaken.

1.1 Study Objectives

The primary objective of the study was to determine the diurnal fluctuation of TC, FC and fecal streptococcus (FS) that could be used in the assessment of the historical data. A pertinent secondary objective was to determine the diurnal fluctuation of the routinely measured dissolved oxygen, temperature, pH, conductivity and turbidity, and to examine their relationship, if any, to the bacterial densities.

2.0 METHODS

2.1 Sample Collection

Samples were collected every hour for a 36-hour period, starting at 7 a.m. on August 9 and ending at 6 p.m. on August 10, 1988. All samples were collected from below surface at midstream, using a metal holder suspended from the bridge on Highway 75. Sampling procedures related to bottle preparation and preservation are described in the Water Quality Branch Sampling Manual (1979). Five sets of cross-sectional samples were also collected during the study period.

2.2 Sample Analyses

Samples were analyzed by the membrane filtration method as described in Biological Analysis of Water and Wastewater (Millipore Corporation, 1987) and in Standard Methods (American Public Health Association, 1985).

The water samples were filtered within 15 minutes of collection and the filters were immediately placed on the appropriate nutrient media. TC were incubated at 35°C for 24 hours, FC at 44.5°C for 24 hours and FS at 35°C for 48 hours. Historical data indicated that 50 ml and 1 ml were the most appropriate sample size to obtain the desired colony counts.

The 50 ml test yielded the optimum colony counts while the 1 ml results were mostly negative. Therefore, results from the 50 ml constitute the data base of this report. When samples were analyzed in replicates, the mean value was calculated.

3.0 RESULTS

The hourly data are presented in Table 1. The TC data set is incomplete because of interferences encountered in the analysis. The interference, at least in part, is believed to be caused by the relatively high concentration of suspended sediments (study mean 81.4 NTU) in the Red River. For the purpose of this study, except when comparing to the historical data, TC counts that were lower than the FC counts were also included.

Summary statistics of the study period, results of the replicate samples, and cross-sectional data are given in Tables 2, 3 and 4, respectively. Table 5 contains the yearly mean and ratios of historical data. A comparison of the historical data and the study data is presented in Table 6. Detailed cross-sectional data are reported in Appendix A. Graphic presentations of bacterial density and concentrations of other parameters are given in Figure 3. Ratios of TC, FC and FS in terms of simple regression are given in Figure 4. The 1976-88 TC and FC mean monthly densities are given in Figure 5. Bacterial densities in relation to DO, temperature, pH, conductivity and turbidity are presented in Appendix B.

4.0 DISCUSSION

4.1 Diurnal Variation and Routine Monthly Samples

Hourly data in Table 1 and Figure 3 show that the bacterial density in the Red River fluctuated substantially during the study period. The range was 101, 38 and 46 for TC, FC and FS, respectively. The standard error in terms of V, the coefficient of variation ($V = \frac{S}{\overline{X}} \times 100$), was 112% for TC and 42% and 49% for FC and FS, respectively. The TC results presented here are clearly influenced by the last two high values observed during the study and the inclusion of values that were lower than the FC values. If these values are not included, the range and coefficient of variation would be substantially lower. However, for the purpose of this study, these values are considered to be essential and are included in further discussion.

Results of replicate analyses in Table 3 show that the analytical variation was substantial and thus, the fluctuation values were undoubtedly influenced by the analytical variation. When the analytical variation was accounted for, only for TC and FS was the diurnal fluctuation significant; even then, it was less than an order of magnitude.

Grouping the data into three arbitrary periods also revealed similar fluctuation patterns, with higher TC densities occurring

during the day and high FS densities occurring during the night (Table 2). Regression plots given in Appendix B also indicate that TC increased with the temperature during the day time while FS actually decreased. For FC, such differences were less pronounced. The higher FS concentration observed during the night period merits further investigation.

Data presented in Table 4 show that the cross-sectional variation was large for bacteria, but it was not significantly different from the analytical variation. Therefore, within the analytical variation, the cross-section was found to be homogeneous.

The above observations lend support to the conclusion that for TC and FS the diurnal fluctuations were more than the analytical variation, but was less than an order of magnitude. For FC the fluctuation was not more than the analytical variation.

4.2 Historical Data and Trend in Bacterial Density

Historical data presented in Figure 2 and in Table 5 show that the TC and FC densities varied substantially more than the study fluctuation and in recent years the density decreased significantly. Evaluation of the data points in Figure 2 indicated that this trend was much influenced by the absence of the high density values observed prior to 1983. Examination of documents on file revealed that all or most of these high densities coincided

with the accidental discharges of the sugarmill or municipal wastes, and their absence from 1983 onwards resulted in lower TC and FC densities.

During 1977-79, there were a number of sugarmill waste discharges and their effect is clearly seen in the observed high TC densities (Figure 2). The higher TC/FC ratio noted for this period is also consistent with the expected effect of the sugarmill waste with high TC densities. The 1976-88 mean monthly density plots in Figure 5 and regression plots in Figure 4 also reveal that in the Red River maximum TC and FC densities do not occur concurrently. Maximum TC densities occurred during the spring runoff and maximum FC densities occurred prior to the spring runoff and in September, coinciding with the municipal lagoon effluent discharges normally occurring during these periods.

The mean FC density of the August 9-10, 1988, study was 21/100 ml while it was 28 for FS (Table 6). If the FC/FS ratio can be applied to this site, 70 km downstream from the nearest point source, the low FC/FS ratio suggests non-human sources. This observation is consistent with the historical data and findings reported by Bell et al. in 1979. In their investigation, Bell and co-workers found that the FC/FS ratio in the Red River at Emerson was about 1 while it was 20 downstream from Winnipeg; clearly reflecting the fecal coliform contributions from the sewage effluent of the City of Winnipeg.

4.3 Bacteria Density in Relation to DO, Temperature, pH, Conductivity and Turbidity

Regression plots in Appendix B show that during the hourly study, TC and FC slightly decreased with increasing DO while FS significantly increased. The DO fluctuation was less than 1 mg/L during the study period and, therefore, its effect, if any, on the facultative coliform bacteria is not considered to be significant. TC increased with increasing temperature while FC and FS decreased. It is noteworthy that the effect of temperature on these bacterial groups varied substantially. All three bacterial groups increased in density with pH, while only FS decreased with increasing conductivity. All decreased with increasing turbidity. This divergent response is well reflected in the poor correlations observed for the three bacterial groups (Figure 4). These observations show that despite some apparent relationships, the bacterial density in the Red River was generally independent of the DO, temperature, pH, conductivity and turbidity. However, it should be noted that the data base was too limited to draw any firm conclusions.

4.4 Diurnal Fluctuation of the Field Measured Water Quality Parameters

4.4.1 Dissolved Oxygen

Diurnal DO fluctuation was evident (Figure 3), but it was limited to less than 1 mg/L. This observation is consistent with the values reported by Chacko and Vaughan (1989) for the Red River, but was substantially lower than the 8 mg/L reported for the Souris River by Munro and Crosley (1984) and the 6 mg/L for the Big Presque Isle Stream reported by Roussel et al. (1988). DO peaked during the night with low temperature and reached the lowest point just around noon. In their studies, Munro and Crosley and Roussel et al. observed that the DO peaked in the afternoon and they attributed this to photosynthetic activity. In the Red River DO peaked during the night and thus, a generalization of DO concentration in a river based on photosynthetic activity is not always valid. The major factor affecting the DO concentration in the Red River appeared to be the water temperature.

4.4.2 Temperature

Temperature data yielded the typical bell-shaped curve skewed to the right, demonstrating the sudden rise and gradual decrease (Figure 3). The range of variation was 6.8°C with the minimum occurring before sunrise and maximum during the afternoon.

4.4.3 pH

Similar to DO, the diurnal pH variation was small and being limited to 0.1 pH units (Figure 3). The increase observed during the afternoon (Figure 3) probably resulted from photosynthetic activity. However, the cause of the maximum values observed prior to midnight is not known.

4.4.4 Conductivity

Conductivity revealed a discernible pattern which generally followed the temperature profile (Figure 3). Since all the conductivity readings were adjusted to 25°C, and since there was no rain, one probable cause was the dissolution of solids with the higher temperature. The range of variation was 65 uS/cm, constituting about 6% deviation from the mean.

4.4.5 Turbidity

Turbidity varied substantially during the study period, yielding high day time values and low night time values (Figure 3). High day time values probably resulted from day time activities such as boating and fishing and increased aeration. The variation pattern was rather inconsistent as high concentrations were detected during the morning of the first day and then during noon of the second day. Since the study mean was relatively high (81.4 NTU), turbidity is an important parameter in the assessment of the Red River water quality.

5.0 CONCLUSIONS

The diurnal fluctuations of all three groups of bacteria (TC, FC, FS) were substantial. However, when the large analytical variation was accounted for, the diurnal fluctuation was less than an order of magnitude.

Since the analytical variation was substantial, replicate analyses of each sample are essential in correctly estimating the bacterial density in the Red River.

The low fecal coliform to fecal streptococci ratio (FC/FS) indicated that much of the bacteria present in the Red River at Emerson are of non-human sources.

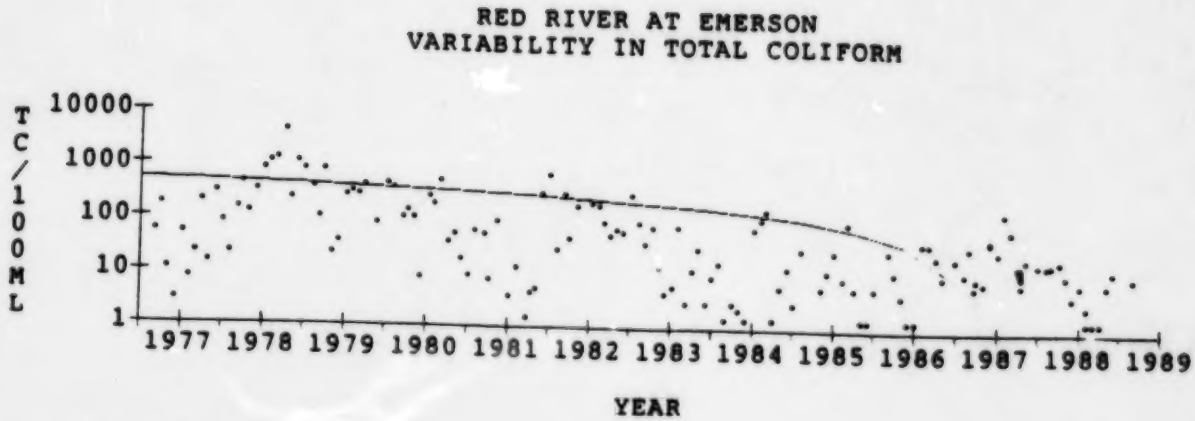
The total and fecal coliform densities in the Red River at Emerson have significantly decreased in recent years. A major contributing factor to this decrease was the absence of the periodically occurring sugar mill or municipal waste releases. The 1976-88 routine monthly data also indicated that total coliform peaked during spring runoff while the maximum fecal coliform densities were detected prior to the spring runoff and in September.

The cross-sectional variation of bacteria was not substantially different from the analytical variation, and the bacterial density was generally independent of DO, temperature, pH, conductivity and turbidity.

The Red River, with the possible exception of turbidity, was virtually homogeneous for DO, temperature, pH and conductivity. The diurnal fluctuations of DO, temperature, pH, conductivity and turbidity were clearly evident but were substantially lower than observed in other rivers.

Figure 1. Red River Basin - Sampling Site

Figure 2. Red River at Emerson - Historical Data



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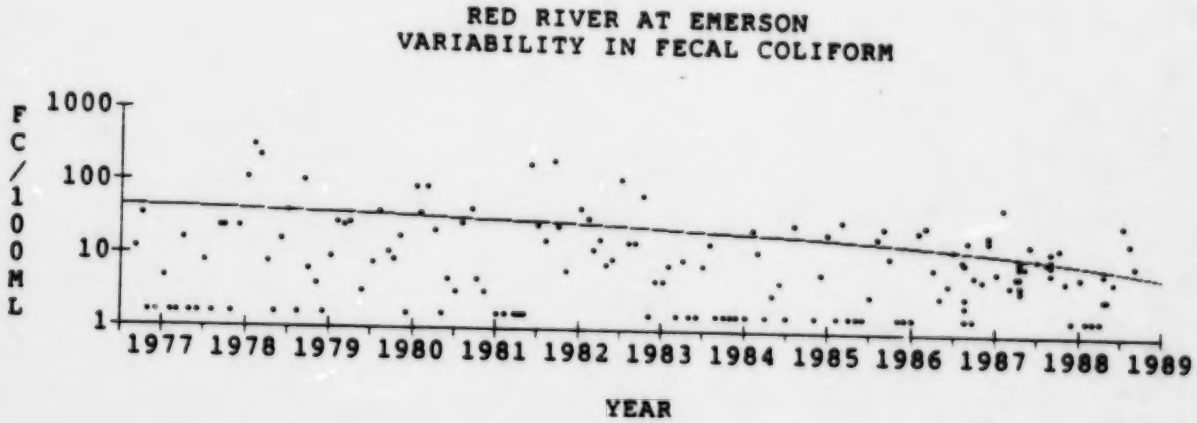
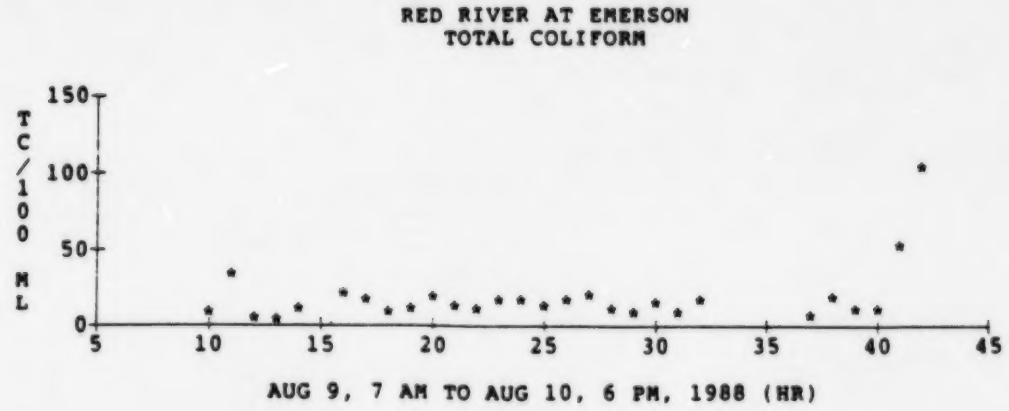
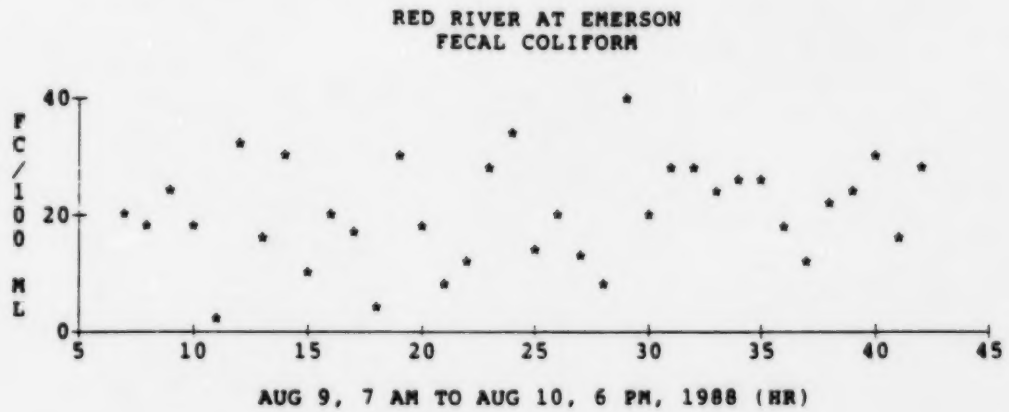


n = 162; r2 0.054; sig = 0.0001

Figure 3. Red River at Emerson - Study Period Density/Concentration





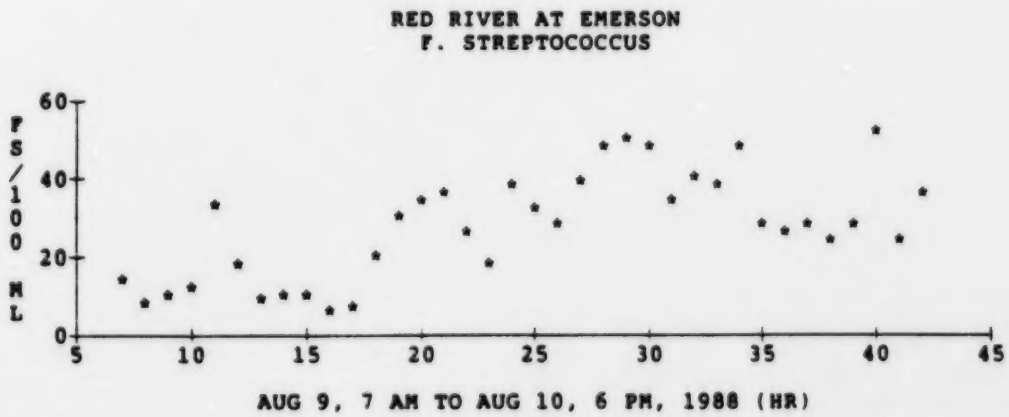
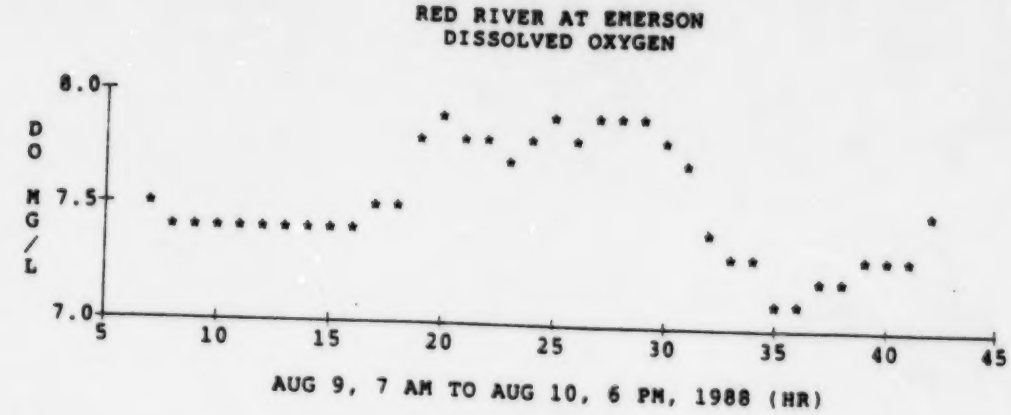
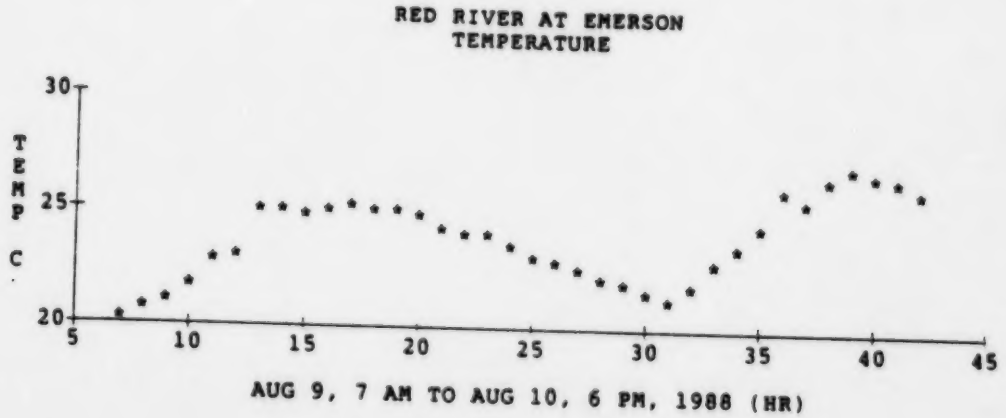


Figure 3. Red River at Emerson - Study Period Density/Concentration (Continued)





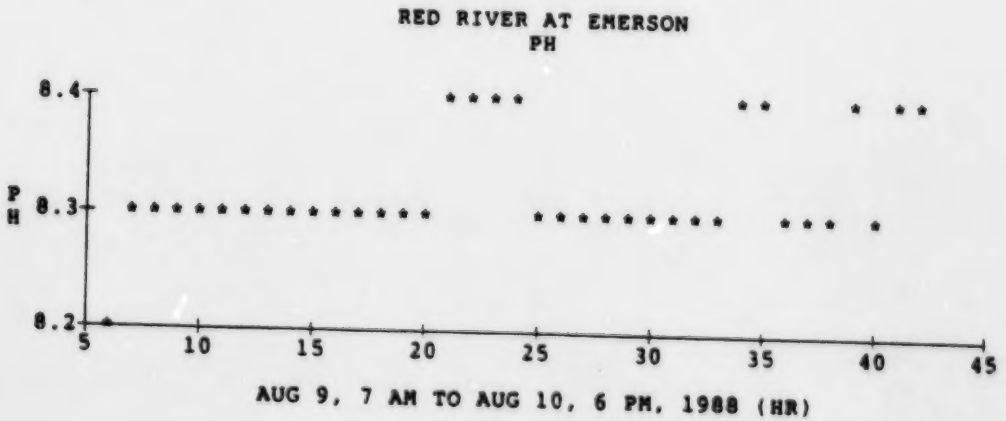
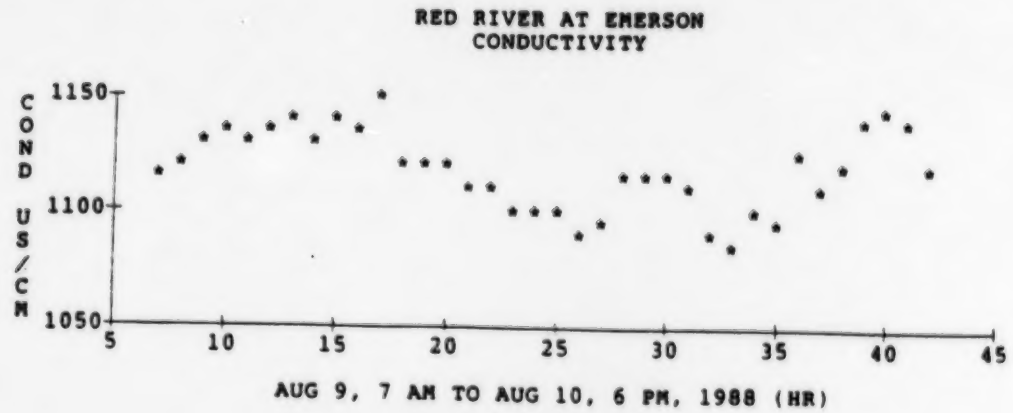


Figure 3. Red River at Emerson - Study Period Density/Concentration (Continued)



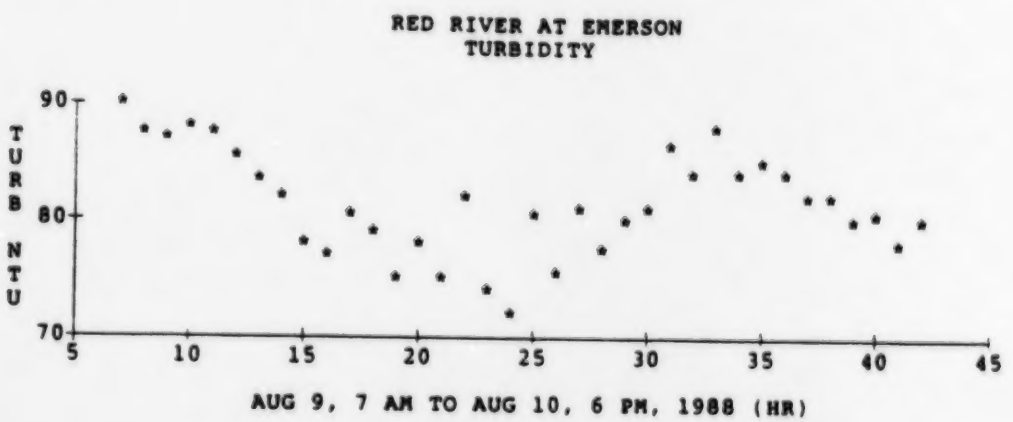
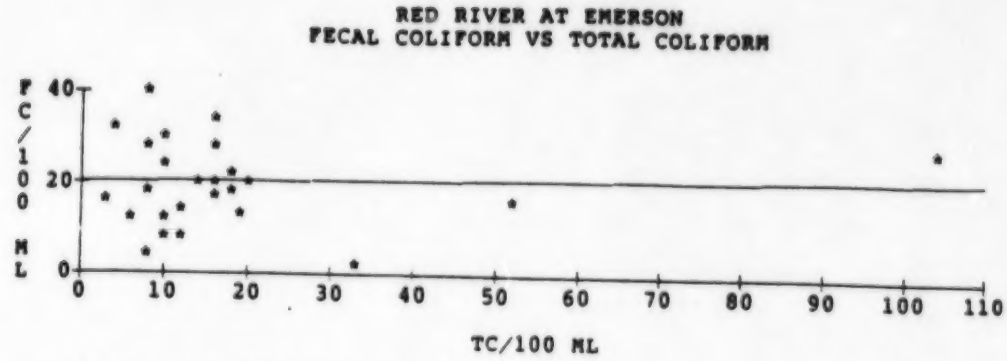


Figure 4. Red River at Emerson - Ratios of Bacterial Groups



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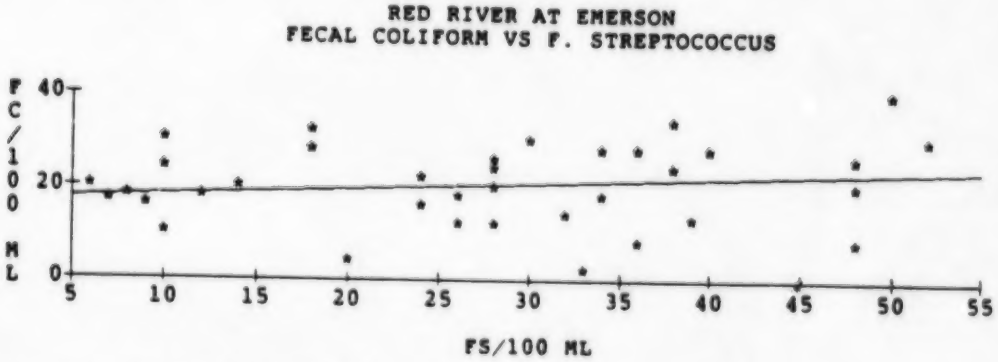

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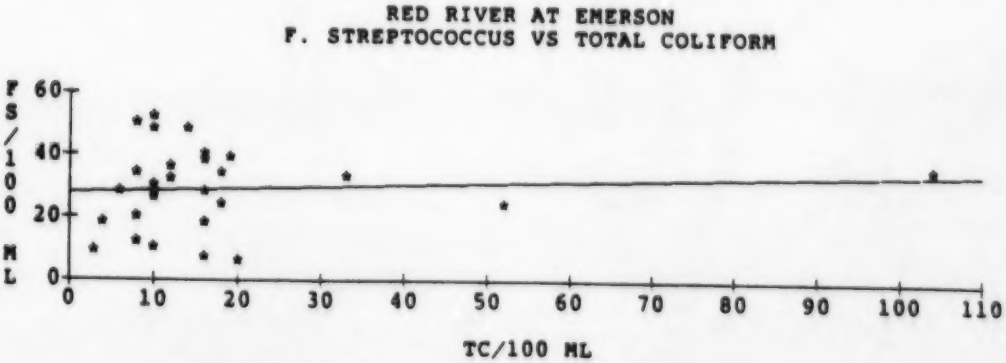

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Figure 5. Red River at Emerson - Mean Monthly Density; 1976-88

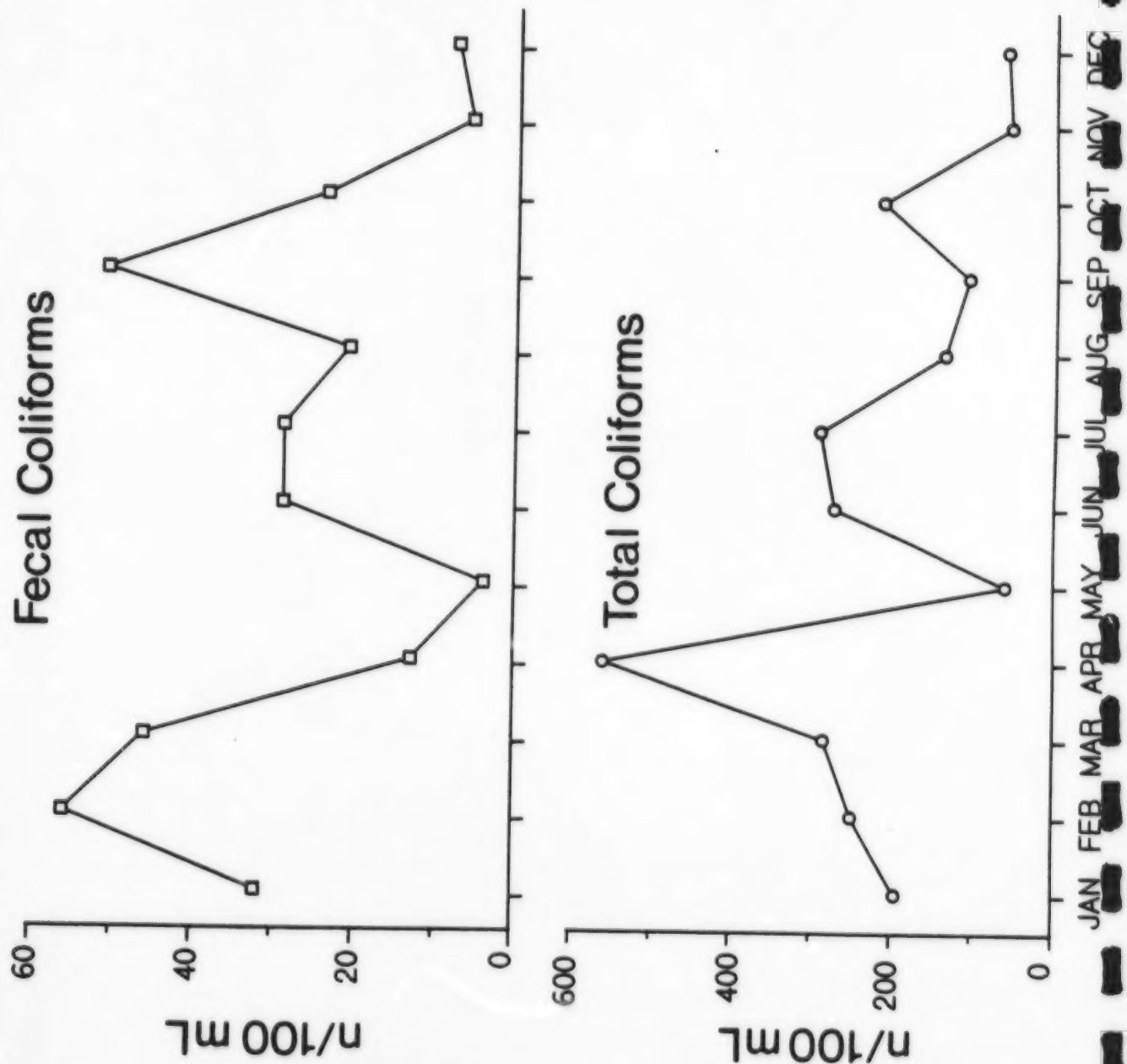

Table 1. Red River at Emerson -- Hourly Data; August 9-10, 1988

DATE	TIME	TEMP. C	TURB. NTU	COND. uS/cm	pH	D.O. mg/L	T.C. /100 ml	F.C. /100 ml	F.S. /100 ml
09	07:00	20.2	90.0	1115	8.3	7.5		20	14
09	08:00	20.7	87.5	1120	8.3	7.4		18	8
09	09:00	21.0	87.0	1130	8.3	7.4		24	10
09	10:00	21.7	88.0	1135	8.3	7.4	8	18	12
09	11:00	22.8	87.5	1130	8.3	7.4	33	2	33
09	12:00	23.0	85.5	1135	8.3	7.4	4	32	18
09	13:00	25.0	83.5	1140	8.3	7.4	3	16	9
09	14:00	25.0	82.0	1130	8.3	7.4	10	30	10
09	15:00	24.8	78.0	1140	8.3	7.4		10	10
09	16:00	25.0	77.0	1135	8.3	7.4	20	20	6
09	17:00	25.2	80.5	1150	8.3	7.5	16	17	7
09	18:00	25.0	79.0	1120	8.3	7.5	8	4	20
09	19:00	25.0	75.0	1120	8.3	7.8	10	30	30
09	20:00	24.8	78.0	1120	8.3	7.9	18	18	34
09	21:00	24.2	75.0	1110	8.4	7.8	12	8	36
09	22:00	24.0	82.0	1110	8.4	7.8	10	12	26
09	23:00	24.0	74.0	1100	8.4	7.7	16	28	18
09	24:00	23.5	72.0	1100	8.4	7.8	16	34	38
10	01:00	23.0	80.5	1100	8.3	7.9	12	14	32
10	02:00	22.8	75.5	1090	8.3	7.8	16	20	28

Table 1. Red River at Emerson -- Hourly Data; August 9-10, 1988 (Continued)

DATE	TIME	TEMP. C	TURB. NTU	COND. uS/cm	pH	D.O. mg/L	T.C. /100 ml	F.C. /100 ml	F.S. /100 ml
10	03:00	22.5	81.0	1095	8.3	7.9	19	13	39
10	04:00	22.1	77.5	1115	8.3	7.9	10	8	48
10	05:00	21.9	80.0	1115	8.3	7.9	8	40	50
10	06:00	21.5	81.0	1115	8.3	7.8	14	20	48
10	07:00	21.2	86.5	1110	8.3	7.7	8	28	34
10	08:00	21.8	84.0	1090	8.3	7.4	16	28	40
10	09:00	22.8	88.0	1085	8.3	7.3		24	38
10	10:00	23.5	84.0	1100	8.4	7.3		26	48
10	11:00	24.4	85.0	1095	8.4	7.1		26	28
10	12:00	26.0	84.0	1125	8.3	7.1		18	26
10	13:00	25.5	82.0	1110	8.3	7.2	6	12	28
10	14:00	26.5	82.0	1120	8.3	7.2	18	22	24
10	15:00	27.0	80.0	1140	8.4	7.3	10	24	28
10	16:00	26.7	80.5	1145	8.3	7.3	10	30	52
10	17:00	26.5	78.0	1140	8.4	7.3	52	16	24
10	18:00	26.0	80.0	1120	8.4	7.5	104	28	36

Table 2. Red River at Emerson
Diurnal Fluctuation (Aug. 9, 7 a.m. - Aug. 10, 6 p.m.)

PARAMETER	STUDY MEAN	7 a.m. - 12 noon		1 p.m. - 10 p.m.		11 p.m. - 6 a.m.	
		Mean	Diff.%	Mean	Diff.%	Mean	Diff.%
T. Coliform/100 ml	17	14	18-	22	29+	13	24-
F. Coliform/100 ml	21	22	5+	20	5-	20	5-
F. Streptococcus/100ml	28	26	7-	23	18-	36	29+
Dissolved Oxygen mg/L	7.5	7.4	1.4-	7.4	1.4	7.8	4+
Temperature C	23.8	22.4	6.1	25.6	7.6	23.0	3.4-
pH	8.3	8.3	0	8.3	0	8.3	0
Conductivity uS/cm	1118	1114	0.4	1131	1.2+	1105	1.2-
Turbidity NTU	81.4	86.4	6.1+	79.7	2.1-	77.9	4.3-

Table 3. Red River at Emerson Results of Replicate Analyses

DATE AND TIME	REPLICATES	TC/100 ml	FC/100 ml	FS/100 ml
88/09/1300	1	8	28	6
	2	4	20	10
	3	4	NA	12
	$\bar{X}$ (S)	5 (2.3)	NA	9 (3.1)
	V	46.0	NA	34.4
88/09/1700	1	10	26	10
	2	16	14	6
	3	18	12	6
	$\bar{X}$ (S)	15 (4.2)	17 (7.6)	7 (2.3)
	V	28.0	44.7	32.9
88/10/0300	1	24	8	32
	2	16	6	44
	3	18	18	42
	$\bar{X}$ (S)	19 (4.2)	11 (6.4)	39 (6.4)
	V	22.1	58.2	16.4

$$V = \frac{S}{\bar{X}} \times 100$$

NA = Not available

Table 4. Red River at Emerson Cross-sectional Data Summary

PARAMETER	TIME	MEAN	STD. DEV.	COEFFICIENT	NUMBER
T. Coliform	88/09/0700	7	3.1	44.3	3
F. Coliform	88/09/0700	15	8.1	54.0	5
F. Streptococcus	88/09/0700	9	5.2	57.8	5
T. Coliform	88/09/1400	16	7.2	45.0	5
F. Coliform	88/09/1400	22	5.5	25.0	5
F. Streptococcus	88/09/1400	10	3.6	36.0	5
T. Coliform	88/09/1500	16	5.9	36.9	4
F. Coliform	88/09/1500	20	5.9	29.5	5
F. Streptococcus	88/09/1500	19	5.0	26.3	5
T. Coliform	88/10/1100	NA	NA	NA	NA
F. Coliform	88/10/1100	25	3.0	12.0	5
F. Streptococcus	88/10/1100	31	2.7	8.7	5
Dissolved Oxygen	88/09/0700	7.4	0.04	0.54	5
Temperature	88/09/0700	20.2	0.1	0.50	5
pH	88/09/0700	8.3	0	0	5
Conductivity	88/09/0700	1117	5.7	0.51	5
Turbidity	88/09/0700	86.6	3.8	4.4	5

$$V = \frac{S}{\bar{X}} \times 100$$

NA = Not available

Table 5. Total and Fecal Coliform Mean and Ratios, 1976-1988.

Year	$TC(\bar{X})$	$FC(\bar{X})$	TC/FC	N
1976*	83.5	15.5	5.4	4
1977	195.6	11.5	17.0	12
1978	1227.5	86.5	14.2	12
1979	309.2	20.7	14.9	11
1980	154.2	37.1	4.2	11
1981	188.5	54.2	3.5	11
1982	131.2	37.5	3.5	12
1983	18.3	6.0	1.4	12
1984	54.5	11.2	4.9	10
1985	24.0	13.7	1.8	11
1986	34.7	14.1	2.5	14
1987	35.7	13.5	2.6	18
1988*	6.5	4.2	1.6	8

* Data available for part of the year only.

Table 6. Statistical Summary of Historical and Study Data

	Historical Data (1976 - 1988)	Study Data (Aug. 9, 10, 1988)
	TOTAL COLIFORM	
Mean	193	31
Std. Dev.	543.9	30.7
Median	33	19
Min.	2	8
Max.	5700	104
Number	147	9
V	282	99
	FECAL COLIFORM	
Mean	25	21
Std. Dev.	50.1	8.7
Median	10	20
Min.	2	2
Max.	390	40
Number	162	36
V	200	41
	FECAL STREPTOCOCCUS	
Mean	NA	28
Std. Dev.	NA	14
Median	NA	28
Min.	NA	6
Max.	NA	52
Number	NA	36
V	NA	50

NA = Not Available

$V = \frac{S}{\bar{X}} \times 100$

6.0 REFERENCES

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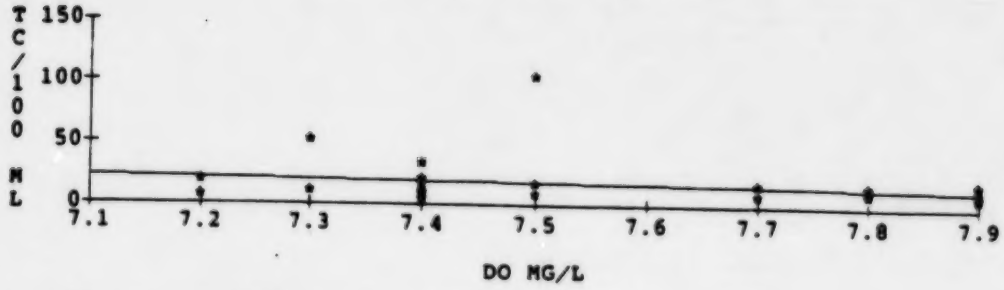
Appendix A

Red River at Emerson
Cross-Sectional Data

Date and Time	1 Temp C	2 Turb NTU	3 Cond uS/cm	4 pH	5 D.O. mg/L	6 T.C. /100 ml	7 F.C. /100 ml	8 F.S. /100 ml
09-AUG-88 07:00	20.2	84.5	1110	8.3	7.4		10	6
09-AUG-88 07:00	20.3	81.0	1120	8.3	7.4	10	6	14
09-AUG-88 07:00	20.2	90.0	1115	8.3	7.5		20	14
09-AUG-88 07:00	20.3	89.5	1115	8.3	7.4	8	26	8
09-AUG-88 07:00	20.2	88.0	1125	8.3	7.4	4	12	2
09-AUG-88 14:00						26	22	14
09-AUG-88 14:00						18	16	4
09-AUG-88 14:00	25.0	82.0	1130	8.3	7.4	10	30	10
09-AUG-88 14:00						8	24	10
09-AUG-88 14:00						18	18	10
09-AUG-88 15:00						20	20	20
09-AUG-88 15:00						12	22	20
09-AUG-88 15:00	24.8	78.0	1140	8.3	7.4		10	10
09-AUG-88 15:00						10	20	22
09-AUG-88 15:00						22	26	22
10-AUG-88 11:00							22	34
10-AUG-88 11:00							28	34
10-AUG-88 11:00	24.4	85.0	1095	8.4	7.1		26	28
10-AUG-88 11:00							28	30
10-AUG-88 11:00							22	30

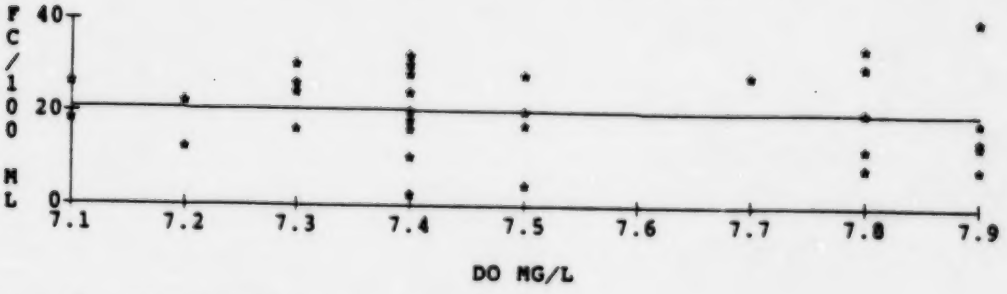
Appendix B. Bacterial Density in Relation to Other Parameters

RED RIVER AT EMERSON
TOTAL COLIFORM VS DISSOLVED OXYGEN



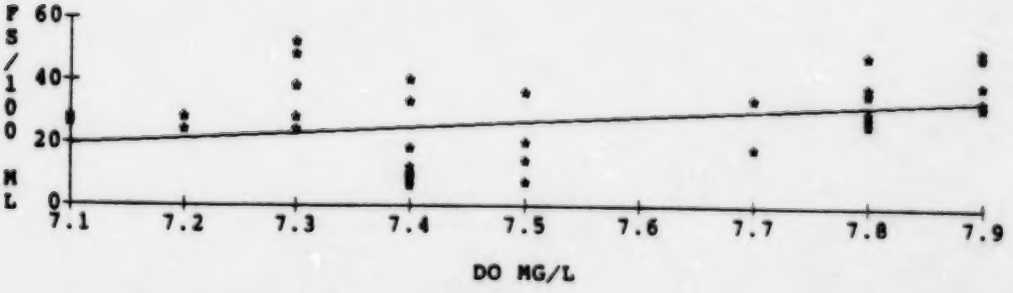
n = 28; r2 = 0.0156; sig = 0.436

RED RIVER AT EMERSON
FECAL COLIFORM VS DISSOLVED OXYGEN



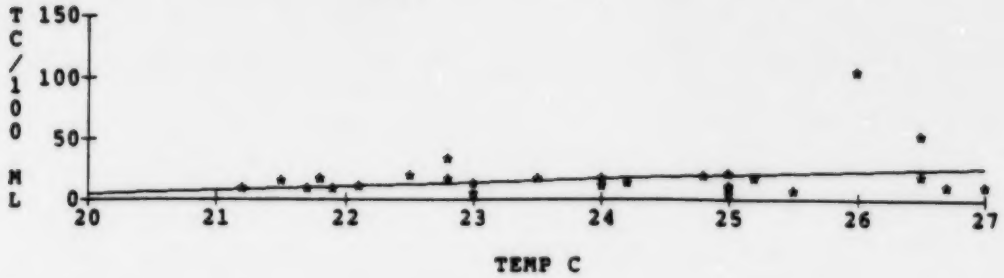
n = 36; r2 = 0.0009; sig = 0.525

RED RIVER AT EMERSON
F. STREPTOCOCCUS VS DISSOLVED OXYGEN



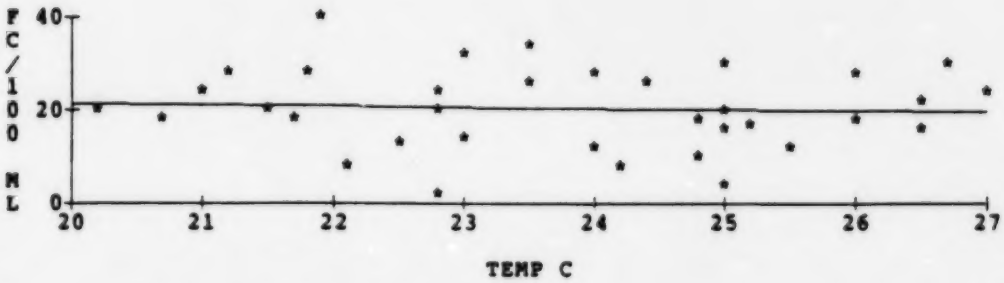
n = 36; r2 = 0.1174; sig = 0.0974

RED RIVER AT EMERSON
TOTAL COLIFORM VS TEMPERATURE



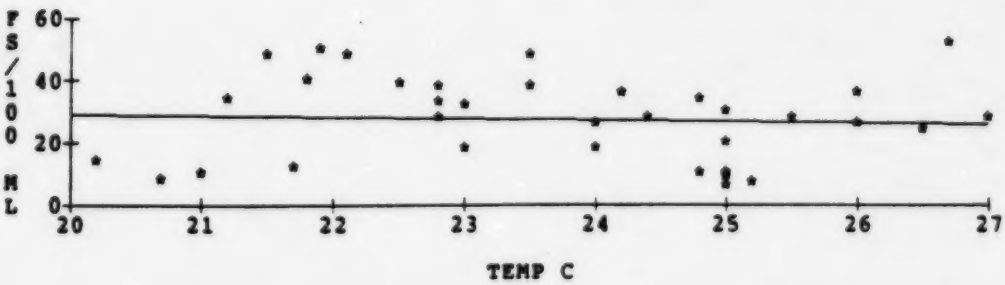
n = 28; r2 = 0.079; sig = 0.2617

RED RIVER AT EMERSON
FECAL COLIFORM VS TEMPERATURE



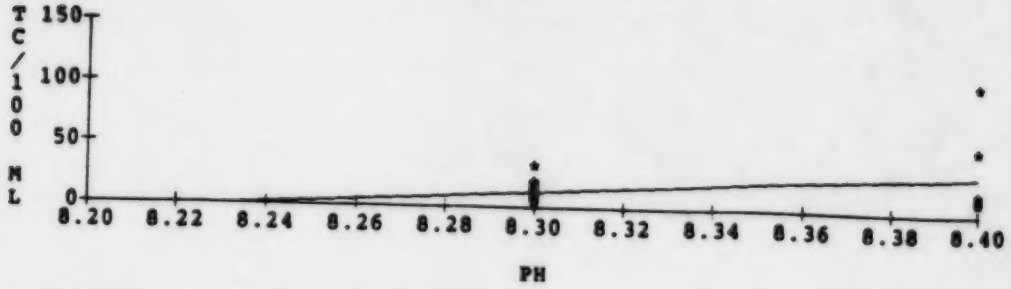
n = 36; r2 = 0.0018; sig = 0.1954

RED RIVER AT EMERSON
F. STREPTOCOCCUS VS TEMPERATURE



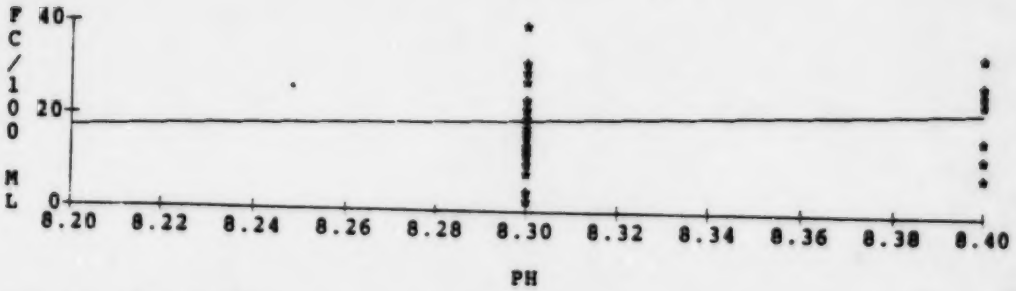
n = 36; r2 = 0.0040; sig = 0.2026

RED RIVER AT EMERSON
TOTAL COLIFORM VS PH



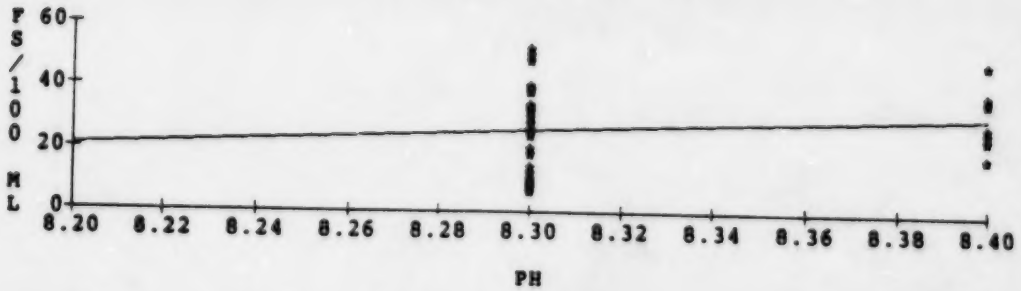
n = 28; r2 = 0.1797; sig = 0.0260

RED RIVER AT EMERSON
FECAL COLIFORM VS PH



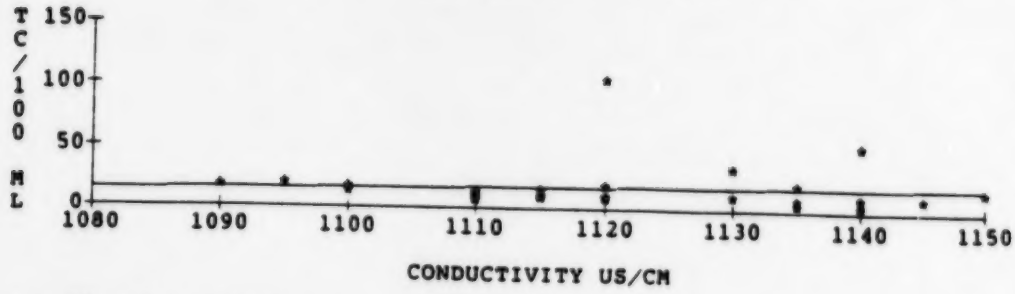
n = 36; r2 = 0.0171; sig = 0.4907

RED RIVER AT EMERSON
F. STREPTOCOCCUS VS PH



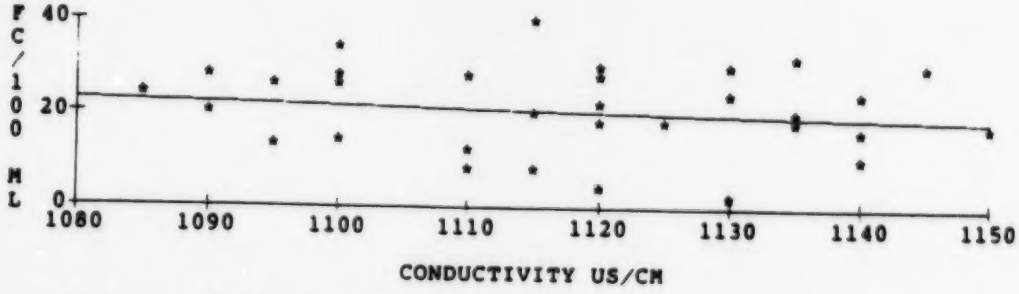
n = 36; r2 = 0.0276; sig = 0.3641

RED RIVER AT EMERSON
TOTAL COLIFORM VS CONDUCTIVITY



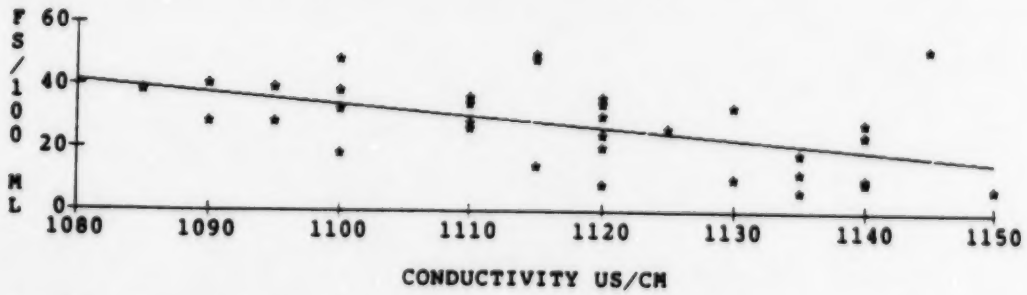
n = 28; r2 = 0.0026; sig = 0.8492

RED RIVER AT EMERSON
FECAL COLIFORM VS CONDUCTIVITY



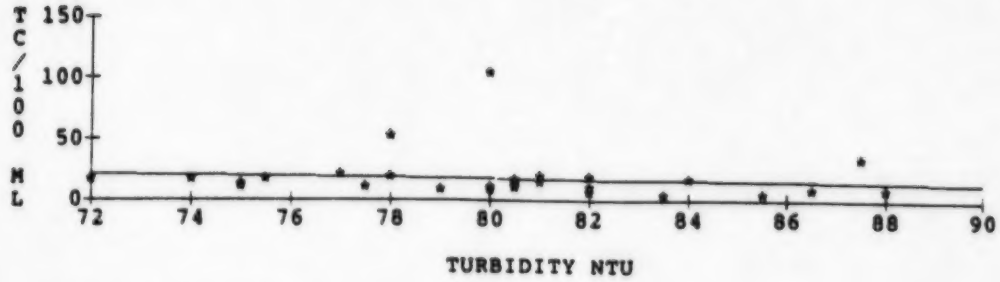
n = 36; r2 = 0.0140; sig = 0.3704

RED RIVER AT EMERSON
F. STREPTOCOCCUS VS CONDUCTIVITY



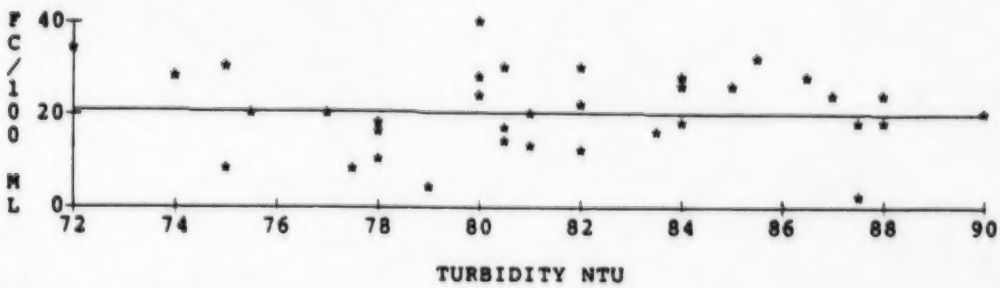
n = 36; r2 = 0.2128; sig = 0.0026

RED RIVER AT EMERSON
TOTAL COLIFORM VS TURBIDITY



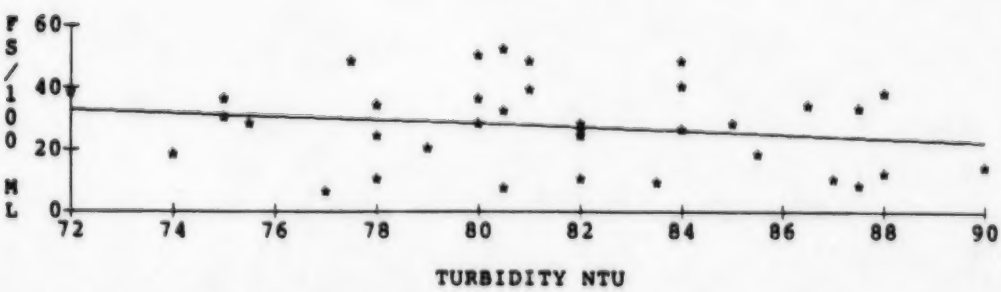
n = 28; r2 = 0.0065; sig = 0.5281

RED RIVER AT EMERSON
FECAL COLIFORM VS TURBIDITY



n = 36; r2 = 0.0007; sig = 0.372

RED RIVER AT EMERSON
F. STREPTOCOCCUS VS TURBIDITY



n = 36; r2 = 0.0346; sig = 0.0869